01 Microbes in Human Welfare

1. Introduction :

- Microbes are present everywhere, in soil, water, air, inside our bodies and that of other animals and plants. They are present even at sites where no other life-form could possibly exist sites such as deep inside the geysers (thermal vents) where the temperature may be as high as 1000^0 C, deep in the soil, under the layers of snow several metres thick, and in highly acidic environments.
- Microbes are diverse, protozoa, bacteria, fungi and microscopic plant viruses, viroids and also prions that are proteinaceous infectious agents.
- Microbes like bacteria and many fungi can be grown on nutritive media to form colonies that can be seen with the naked eyes. Such cultures are useful in studies on micro-organisms.

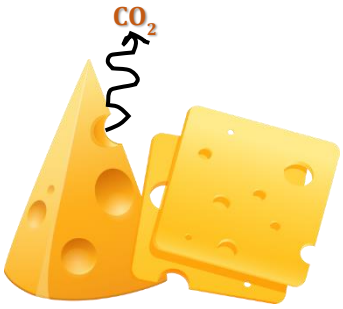
2. Microbes in Household Products :

(A) Curd :

- Micro-organisms such as ***Lactobacillus*** and others commonly called **lactic acid bacteria (LAB)** grow in milk and convert it to **curd**. During growth, the LAB produce acids that **coagulate** and partially digest the milk proteins.
- A small amount of curd added to the fresh milk as **inoculum** or **starter** contain millions of LAB, which at suitable temperatures multiply, thus converting milk to curd, which also improves its nutritional quality by increasing **vitamin B^{12}**. In our stomach too, the LAB play very beneficial role in **checking disease** causing microbes.

(B) Cheese :

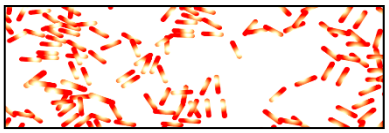
- Cheese is one of the oldest food items in which microbes were used.
- Different varieties of cheese are known by their characteristic **texture, flavour and taste**, the specificity coming from the microbes used. For example, the large holes in **'Swiss cheese'** are due to production of a large amount of CO_2 by a bacterium named ***Propionibacterium sharmanii***.
- The **'Roquefort cheese'** are ripened by growing a specific fungi on pspthem, which gives them a particular flavour.
- Nearly 400 varieties of cheese available which can be classified into following type.



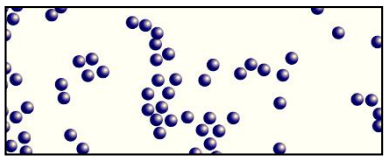
	Type of Cheese	Micro Organisms used for ripening
1.	**Soft** (Camembert cheese)	*Penicillium camemberti*
2.	**Semi-hard** (Roquefort cheese)	*Penicillium roqueforti*
3.	**Hard** (Swiss cheese)	*Propionibacterium sharmanii*

(C) Other Products :

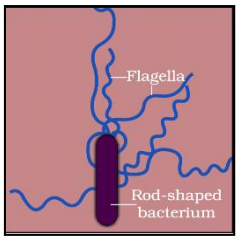
- The **dough**, which is used for making foods such as **dosa** and **idli** is also fermented by bacteria. The puffed-up appearance of dough is due to the production of CO_2 gas.
- Similarly the dough, which is used for making **bread,** is fermented using **baker's yeast** (*Saccharomyces cerevisiae*).
- A number of traditional drinks and foods are also made by fermentation by the microbes. '**Toddy**', a traditional drink of some parts of southern India is made by **fermenting** sap from palms.
- Microbes are also used to ferment fish, soyabean and bamboo shoots to make foods.



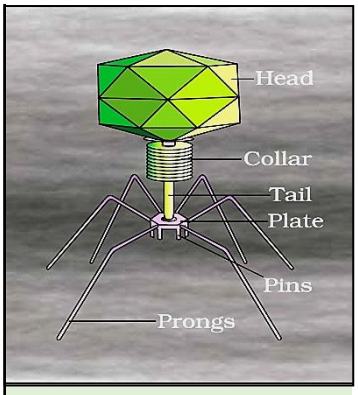
Bacteria :
(a) Rod shaped magnified 1500 X



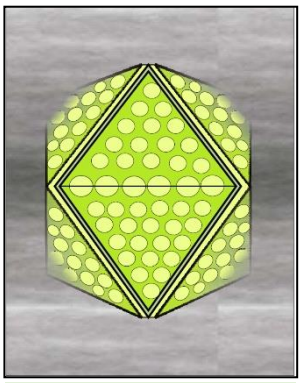
Bacteria :
(b) Spherical shaped magnified 1500 X



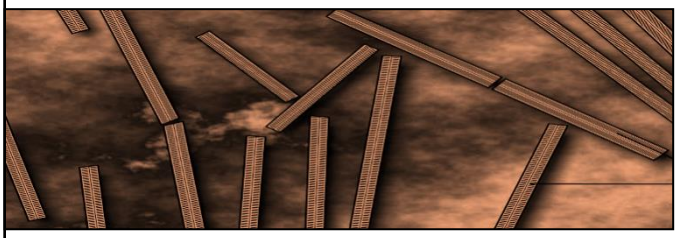
Bacteria :
(c) A rod shaped bacterium showing flagella magnified 1500 X



Virus :
(a) bacteriphage

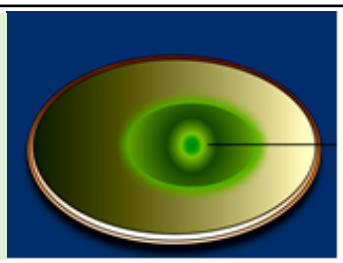


Virus :
(b) Adenovirus which causes



Virus:
(c) A rod shaped Tobacco Mosaic Virus (TMV) Magnified about 1,00,000 – 1,50,000 X

(a) Colonnies of bacteria growing in a petri dish



(b) Fungal colony growing in a petri dish

3. Microbes in Industrial Products :

Even in industry, microbes are used to synthesise a number of products valuable to human beings. Beverages and antibiotics are some examples. Production on an industrial scale, requires growing microbes in very large vessels called fermenters.

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(A) Alcoholic (Fermented) Beverages:

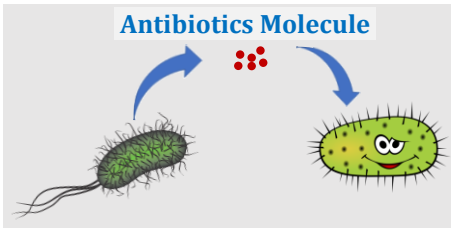
- Microbes especially yeasts have been used from time immemorial for the production of beverages like wine, beer, whisky, brandy or rum. For this purpose, the same yeast ***Saccharomyces cerevisiae*** used for bread-making and commonly called **brewer's yeast**, is used for fermenting malted cereals and fruit juices, to produce ethanol.
- Depending on the type of the raw material used for **fermentation** and the type of processing (with or without distillation) different types of alcoholic drinks are obtained.

Wine and beer are produced without distillation whereas whisky, brandy and rum are produced by distillation of the fermented broth.

Some other common products of yeast fermentation are :

(i) Beer – It is produced from *Hordeum Vulgare* (Barely) malt and alcohol content is 3-6%
(ii) Wine – Produced from grapes, alcohol content is 10-20%.
(iii) Brandy – Produced by distillation of wine and alcohol content is 60-70%.
(iv) Gin – Produced from European Rye-Scale cereal, alcohol content is 40%.
(v) Rum – Produced from Molasses of Sugarcane and alcohol contents is 40%.

(B) Antibiotics :



- The term was coined by Selman Waksman (1942).
- Antibiotics produced by microbes are regarded as one of the most significant discoveries of the **twentieth century** and have greatly contributed towards the welfare of the human society.
- *Anti* is a Greek word that means 'against', and *bio* means 'life', together they mean 'against life' (in the context of disease-causing organisms); whereas with reference to human beings, they are 'pro life' and not against.
- Antibiotics are chemical substances, which are produced by some microbes and can kill or retard the growth of other (disease-causing) microbes.

- You are familiar with the commonly used antibiotic Penicillin. Do you know that Penicillin was the first antibiotic to be discovered and it was a chance discovery? Alexander Fleming while working on ***Staphylococci*** bacteria, once observed a mould growing in one of his unwashed culture plates around which *Staphylococci* could not grow. He found out that it was due to a chemical produced by the mould and he named it Penicillin after the mould ***Penicillium notatum***.

However, its full potential as an effective antibiotic was established much later by **Ernest Chain** and **Howard Florey**. This antibiotic was extensively used to treat American soldiers wounded in World War II. Fleming, Chain and Florey were awarded the Nobel Prize in 1945, for this discovery.

- After Penicillin, other antibiotics were also purified from other microbes. Antibiotics have greatly improved our capacity to treat deadly diseases such as plague, whooping cough (kali khansi), diphtheria (gal ghotu) and leprosy (kusht rog), which used to kill millions all over the globe. Today, we cannot imagine a world without antibiotics.

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(C) Organic Acids:

Some organic acids are manufactured by employing fermentation activities of Fungi and others of Bacteria.

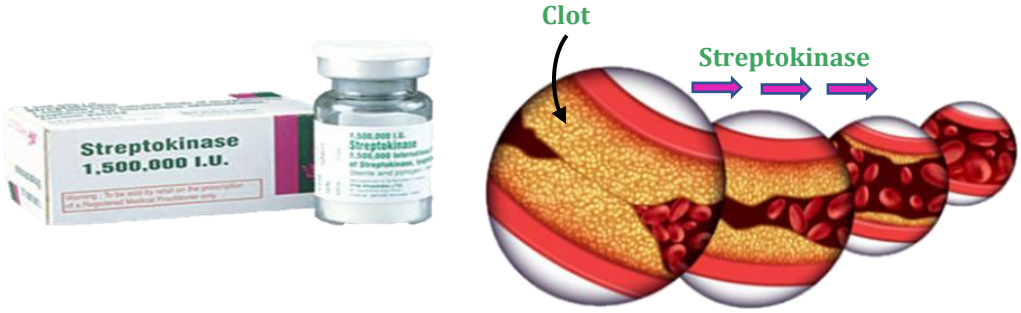
For example:

S.No.	Organic acid	Microbes	Type of Microbes
1	Citric acid	*Aspergillus niger*	Fungus
2	Acetic acid (Vinegar)	*Acetobacter aceti*	Bacteria
3	Butyric acid	*Clostridium butylicum*	Bacteria
4	Lactic acid	*Lactobacillus sp*	Bacteria

(D) Enzymes :

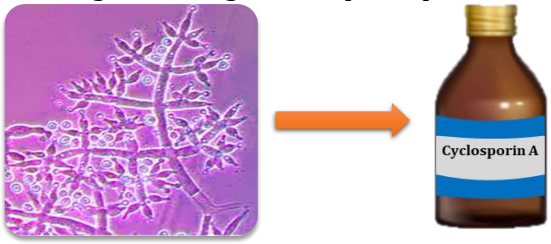
- The bottle juices are clarified by the use of pectinases and protease.
- **Lipases** are used in detergent formulations and are helpful in removing oily stains from the laundry. This is because the bottled juices are clarified by the use of pectinases and proteases.

- **Streptokinase/Tissue Plasminogen Activator :** produced by the bacterium *Streptococcus* and modified by genetic engineering is used as a '**clot buster**' for removing clots from the blood vessels of patients who have undergone myocardial infarction leading to heart attack.



(E) Bioactive Molecule :

- **Cyclosporin A** that is used as an **immunosuppressive** agent in organ-transplant patients is produced by the **fungus *Trichoderma polysporum*.**
- **Statins** produced by the yeast ***Monascus purpureus*** have been commercialised as **blood-cholesterol lowering agents**. It acts by competitively inhibiting the enzyme responsible for synthesis of cholesterol.



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4. Microbes as Biocontrol Agents :

- Biocontrol refers to the use of biological methods for controlling plant diseases and pests. In modern society, these problems have been tackled increasingly by the use of chemicals – by use of insecticides and pesticides.
- These chemicals are toxic and extremely harmful, to human beings and animals alike, and have been polluting our environment (soil, ground water), fruits, vegetables and crop plants.
- Our soil is also polluted through our use of weedicides to remove weeds.

(A) Biological control of pests and diseases:

- In agriculture, there is a method of controlling pests that relies on **natural predation** rather than introduced chemicals.
- A key belief of the organic farmer is that biodiversity furthers health. The more variety a landscape has, the more sustainable it is.
- The organic farmer, therefore, works to create a system where the insects that are sometimes called pests are not eradicated, but instead are kept at manageable levels by a complex system of checks and balances within a living and vibrant ecosystem.
- Contrary to the 'conventional' farming practices which often use chemical methods to kill both useful and harmful life forms indiscriminately, this is a holistic (integrated) approach that seeks to develop an understanding of the webs of interaction between the myriad (incalculable) of organisms that constitute the field fauna and flora.
- The organic farmer holds the view that the eradication of the creatures that are often described as pests is not only possible, but also undesirable, for without them the beneficial predatory and parasitic insects which depend upon them as food or hosts would not be able to survive. Thus, the use of biocontrol measures will greatly reduce our dependence on toxic chemicals and pesticides.
- An important part of the biological farming approach is to become familiar with the various life forms that inhabit the field, predators as well as pests, and also their life cycles, patterns of feeding and the habitats that they prefer. This will help develop appropriate means of biocontrol.

(B) Biopesticides

Biopesticides are those biological agents that are used for control of weeds, insects and pathogens. The micro-organisms used as biopesticides include viruses, bacteria, fungi, protozoa and mites.

(i) Bacteria (*Bacillus thuringiensis*) :

- *Bacillus thuringiensis* is the example of soil bacterium. Spores of this bacterium produce the insecticidal Cry protein. Therefore, spores of this bacterium kill larvae of certain insects.
- The commercial preparations of *B. thuringiensis* contain a mixture of spores, Cry protein. This bacterium was the first biopesticide to be used on a commercial scale in the world.
- An example of microbial biocontrol agents that can be introduced in order to control butterfly caterpillars is the bacteria *Bacillus thuringiensis* (often written as Bt). These are available in sachets as dried spores which are mixed with water and sprayed onto vulnerable plants such as *brassicas* and fruit trees, where these are eaten by the insect larvae. In the gut of the larvae, the toxin is released and the larvae get killed.
- The bacterial disease will kill the caterpillars, but leave other insects unharmed. Because of the development of methods of genetic engineering in the last decade or so, the scientists have introduced *B. thuringiensis* toxin genes into plants. Such plants are resistant to attack by insect pests.
- **Bt-cotton** is one such example, which is being cultivated in some states of our country.

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(ii) Beetle :

The very familiar beetle with red and black markings-the Ladybird are useful to get rid of **aphids**.

(iii) Dragonflies :

Dragonflies are useful to get rid of **mosquitoes**.

(iv) Fungus (*Trichoderma*) :

- Fungal pathogens are attractive biocontrol agents for weed control in view of their host specificity and ease in production and inoculation in the field.
- A biological control being developed for use in the treatment of plant disease is the fungus *Trichoderma*. ***Trichoderma*** species are **free-living fungi** that are very common in the root ecosystems.
- They are effective biocontrol agents of several plant pathogens.

(v) Virus (Baculoviruses) :

- Baculoviruses are pathogens that attack **insects** and other **arthropods**.
- The majority of baculoviruses used as biological control agents are in the genus **Nucleopolyhedrovirus.**
- These viruses are excellent candidates for species-specific, narrow spectrum insecticidal application. They have been shown to have no negative impacts on plants, mammals, birds, fish or even on non-target insects.
- This is especially desirable when beneficial insects are being conserved to aid in an overall **integrated pest management (IPM) programme**, or when an ecologically sensitive area is being treated.

Ladybird

Aphid

Dragonfly

Mosquito

5. Microbes as Biofertilisers :

- The use of the chemical fertilisers to meet the ever-increasing demand of agricultural product has contributed significantly to this pollution. Of course, we have now realised that there are problems associated with the overuse of chemical fertilisers and there is a large pressure to switch to organic farming (the use of biofertilisers).
- **Biofertilisers**: are organisms that enrich the nutrient quality of the soil. The main sources of biofertilisers are bacteria, fungi and cyanobacteria.

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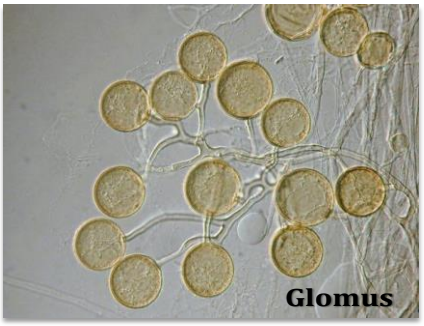
(A) Bacteria:

- The nodules on the roots of leguminous plants formed by the symbiotic association of ***Rhizobium***.
- These bacteria fix atmospheric nitrogen into organic forms, which is used by the plant as nutrient.
- Other bacteria can fix atmospheric nitrogen while free-living in the soil (examples ***Azospirillum*** and ***Azotobacter***), thus enriching the nitrogen content of the soil.

(B) Fungi:

- Fungi are also known to form symbiotic associations with plants (mycorrhiza). Many members of the genus ***Glomus*** form mycorrhiza.
- The fungal symbiont in these associations absorbs phosphorus from soil and passes it to the plant. Plants having such associations show other benefits also, such as resistance to root-borne pathogens, tolerance to salinity and drought, and an overall increase in plant growth and development.



(C) BGA (Blue Green Algae) / Cyanobacteria :

- Cyanobacteria are autotrophic microbes widely distributed in aquatic and terrestrial environments many of which can fix atmospheric nitrogen, ***e.g.*** *Anabaena*, *Nostoc*, *Oscillatoria,* etc. In paddy fields, cyanobacteria serve as an important biofertiliser. Blue green algae also add organic matter to the soil and increase its fertility.
- **Biofertilisers are a low-cost input and they do not pollute the environment. They are used to replenish soil nutrients. They also reduce the dependence on chemical fertilisers and also help to use organic farming.**

6. Microbes in Production of Biogas :

- Biogas is a mixture of gases (containing predominantly **methane**) produced by the microbial activity and which may be used as fuel.
- Microbes produce different types of gaseous end-products during growth and metabolism. The type of the gas produced depends upon the microbes and the organic substrates they utilise. In the examples cited in relation to fermentation of dough, cheese making and production of beverages, the main gas produced was **CO_2.**
- However, certain bacteria, which grow anaerobically on cellulosic material, produce large amount of methane along with CO_2 and H_2. These bacteria are collectively called **methanogens**, and one such common bacterium is ***Methanobacterium*.**
- **Methanogens** are commonly found in the anaerobic sludge during sewage treatment. These bacteria are also present in the **rumen** (a part of stomach) of cattle. A lot of cellulosic material present in the food of cattle is also present in the rumen. In rumen, these bacteria help in the breakdown of cellulose and play an important role in the nutrition of cattle.
- Thus, the excreta (dung) of cattle, commonly called *gobar*, is rich in these bacteria. Dung can be used for generation of biogas, commonly called *gobar gas*.

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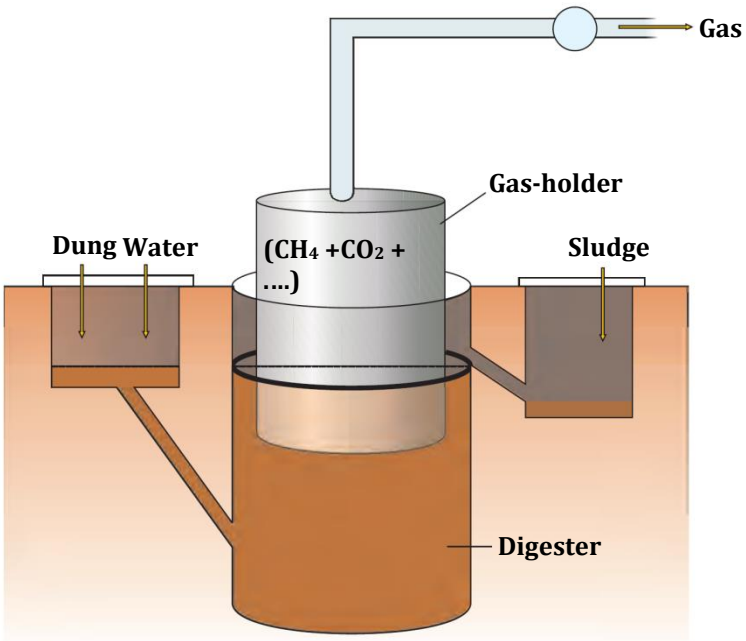
Bio-Gas Plant :

- The biogas plant consists of a concrete tank (10-15 feet deep) in which bio-wastes are collected and a slurry of dung is fed.
- A floating cover is placed over the slurry, which keeps on rising as the gas is produced in the tank due to the microbial activity.
- The biogas plant has an outlet, which is connected to a pipe to supply biogas to nearby houses.
- The spent slurry is removed through another outlet and may be used as fertiliser. Cattle dung is available in large quantities in rural areas where cattle are used for a variety of purposes. So biogas plants are more often built in rural areas.



A typical biogas plant

- The biogas thus produced is used for cooking and lighting. The technology of biogas production was developed in India mainly due to the efforts of **Indian Agricultural Research Institute (IARI)** and **Khadi and Village Industries Commission (KVIC).**
- The organic wastes from the farmhouse cow dung, wastes, urine, faeces etc. can be used economically for producing of **Gobar gas** (Bio gas). It consists of **methane** (50-70%), **CO_2** (30-40%) and traces of hydrogen, nitrogen and hydrogen sulphide.
- Biogas produced by anaerobic fermentation of waste biomass.

Anaerobic fermentation of waste biomass can be visualised in three stages :

(a) First stage :

- The **facultative anaerobic microbes** degrade the **complex polymers to simple monomers** by enzymatic action.
- The Polymers like cellulose, hemicellulose, proteins and lipids get degraded into monomers but **lignins** and inorganic salts are left as residue because they do not degraded.

(b) Second stage :

Monomers are converted into organic acids by microbial action under partially aerobic conditions which are finally converted to **acetic acid**.

(c) Third stage :

- **Acetic acid is oxidised into methane** by the activity of anaerobic methanogenic bacteria.
- In this whole process **digestion of cellulose takes place at very slow rate so that it is the "rate limiting factor in biogas production**".

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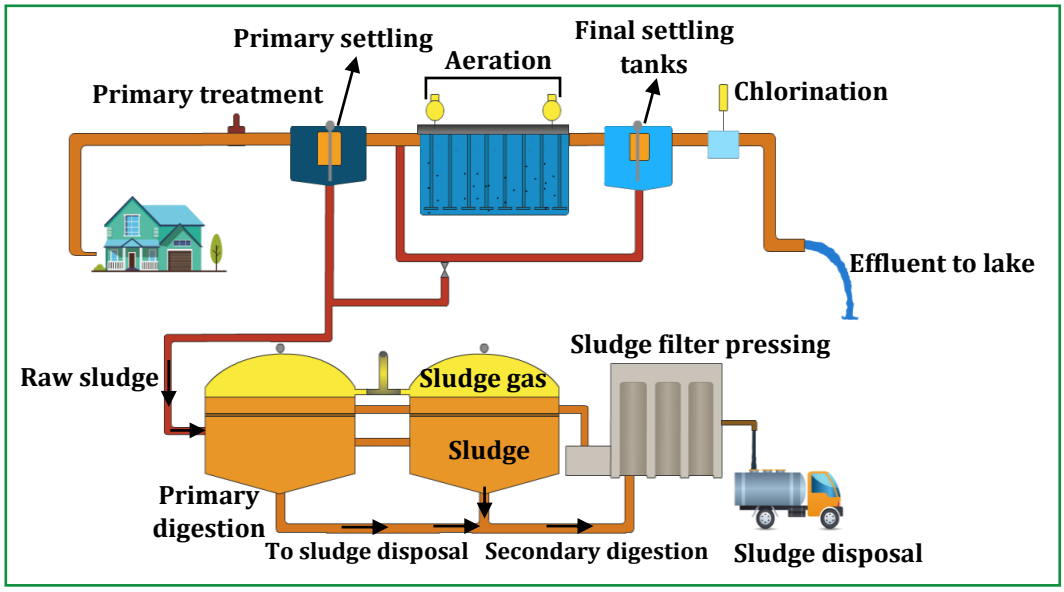
7. Microbes in Sewage Treatment :



- We know that large quantities of waste water are generated every day in cities and towns. A major component of this waste water is human excreta.
- This municipal waste water is also called sewage. It contains large amounts of organic matter and microbes. Many of which are pathogenic.
- Before disposal, hence, sewage is treated in sewage treatment plants (STPs) to make it less polluting. Treatment of waste water is done by the heterotrophic microbes naturally present in the sewage. This treatment is carried out in two stages:

(A) Primary Treatment :

- These treatment steps basically involve physical removal of particles – large and small – from the sewage through filtration and sedimentation.
- These are removed in stages;
  (a) **Sequential filtration:** Floating debris is removed at this stage.
  (b) **Sedimentation:** Then the grit (soil and small pebbles) are removed at this stage.
- All solids that settle in **primary settling tank** form the **primary sludge**, and the supernatant forms the **primary effluent**. The effluent from the **primary settling tank** is taken for **secondary treatment**.

(B) Secondary Treatment or Biological Treatment :

Step 1:

- The primary effluent is passed into large aeration tanks, where it is constantly agitated mechanically, and air is pumped into it. This allows vigorous growth of useful aerobic microbes into **flocs (masses of bacteria associated with fungal filaments to form mesh like structures)**. While growing, these microbes consume the major part of the organic matter in the effluent.
- This significantly reduces the BOD (biochemical oxygen demand) of the effluent.

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- **BOD** refers to the amount of the oxygen that would be consumed if all the organic matter in one litre of water were oxidised by bacteria.
- The sewage water is treated till the BOD is **reduced**. The BOD test measures the rate of uptake of oxygen by micro-organisms in a sample of water and thus, indirectly, BOD is a measure of the organic matter present in the water. The greater the BOD of waste water, more is its polluting potential.

Step 2:

- Once the BOD of sewage or waste water is reduced significantly, the effluent is then passed into a settling tank where the bacterial 'flocs' are allowed to sediment. This sediment is called **activated sludge**.
- **A small part of the activated sludge is pumped back into the aeration tank to serve as the inoculum.**
- The remaining major part of the sludge is pumped into large tanks called **anaerobic sludge digesters**. Here, other kinds of bacteria, which grow anaerobically, digest the bacteria and the fungi in the sludge.
- During this digestion, bacteria produce a mixture of gases such as methane, hydrogen sulphide and carbon dioxide. These gases form **biogas** and can be used as source of energy as it is inflammable.
- The effluent from the secondary treatment plant is generally released into natural water bodies like rivers and streams.

You can appreciate how microbes play a major role in treating millions of gallons of waste water everyday across the globe. This methodology has been practiced for more than a century now, in almost all parts of the world. Till date, no manmade technology has been able to rival the microbial treatment of sewage. You are aware that due to increasing urbanisation, sewage is being produced in much larger quantities than ever before. However, the number of sewage treatment plants has not increased enough to treat such large quantities. So, the untreated sewage is often discharged directly into rivers leading to their pollution and increase in water-borne diseases.

The Ministry of Environment and Forests has initiated **Ganga Action Plan** and **Yamuna Action Plan** to save these major rivers of our country from pollution. Under these plans, it is proposed to build a large number of sewage treatment plants so that only treated sewage may be discharged in the rivers.

SPECIAL POINTS

(1) Single Cell Protein (SCP) :

- It is microbial biomass. This biomass is obtained from both mono and multi cellular microorganism. Single cell protein can be produced using algae, fungi, yeast and bacteria.
- Conventional agricultural production of cereals, pulses, vegetables, fruits, etc., may not be able to meet the demand of food at the rate at which human and animal population is increasing.
- The shift from grain to meat diets also creates more demand for cereals as it takes **3-10 Kg of grain to produce 1 Kg of meat by animal farming.**
- More than 25 per cent of human population is suffering from hunger and malnutrition. One of the alternate sources of proteins for animal and human nutrition is **Single Cell Protein (SCP).**

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- Microbes are being grown on an industrial scale as source of good protein.
- Microbes like ***Spirulina*** can be grown easily on materials like waste water from potato processing plants (containing starch), straw, molasses, animal manure and even sewage, to produce large quantities and can serve as food rich in protein, minerals, fats, carbohydrate and vitamins. Incidentally such utilisation also reduces environmental pollution.
- It has been calculated that a 250 Kg cow produces 200 gm of protein per day. In the same period, 250g of a micro-organism like ***Methylophilus methylotrophus***, because of its high rate of biomass production and growth, can be expected to produce 25 tonnes of protein.
- The fact that mushrooms are eaten by many people and large scale mushroom culture is a growing industry makes it believable that microbes too would become acceptable as food.

(2) Plants as sources of hydrocarbons for producing petroleum :

Melvin Calvin has identified certain plants which produce hydrocarbons. The plants of **Euphorbiaceae**, **Asclepiadaceae** and **Apocyanaceae** produce **latex** a milky secretion which contains hydrocarbons. ***e.g.*** Jatropha

(3) Alcohol as fuel (bioethanol) :-

- Ethanol (C_2H_5OH) can be partly or wholly substituted for petrol in automobiles after suitable modifications in Engines.
- Alcohol has been successfully used as motor fuel in **Brazil** and it is the first leading country in the world.
- Recently Govt. of India has allowed mixing of alcohol (5%) in petrol.

BEGINNER'S BOX-1 — MICROBES IN HUMAN WELFARE

1. Which of the following microorganisms is used in swiss cheese?
(1) *Propionibacterium* (2) *Geotrichum*
(3) *Penicillium* (4) *Streptococcus*

2. In Swiss cheese, big holes are made by a: -
(1) bacterium producing methane gas
(2) machine
(3) fungus releasing a lot of gases while its metabolic activities
(4) bacterium producing large quantities of carbon dioxide

3. Toddy the traditional drink is made by: -
(1) Fermenting sap from palms (2) Fermenting milk
(3) Juice of leaf of bamboo (4) Fermenting the grains

4. Which biocontrol agent in very common in root ecosystem & is effective against several plant pathogens?
(1) Baculoviruses (2) *Trichoderma*
(3) Nucleopolyhedro virus (4) Ladybird beetle & Dragonflies

BEGINNER'S BOX — ANSWERS KEY

BEGINNER'S BOX-1	Que.	1	2	3	4
	Ans.	1	4	1	2

ESSENCE

Microbes in Human Welfare

- **House hold products**
  - **Curd** : Lactic Acid Bacteria (LAB)
    - Vitamin B_{12} (nutritional quality)
    - Checking disease causing microbes
  - **Bread** : (Baker's yeast)
    Saccharomyces cerevisiae
  - **Cheese**
    - Swiss cheese – *Propionibacterium sharmanii*
    - Roque Fort cheese – Specific fungi
- **Industrial products**
  - **Fermented Beverages**
    Brewer's yeast – *Saccharomyces cerevisiae*
    With distillation – Whisky, brandy and rum
    Without distillation – Wine and Beer
  - **Antibiotics**
    Penicillin
    - *Penicillium notatum*
    - Discovered by Alexander Fleming
    - Established by Ernest chain and Howard Florey
  - **Chemicals**
    - Organic acids
    - Citric acid *(Aspergillus niger)*
    - Acetic acid *(Acetobacter acetic)*
    - Butyric acid *(Clostridium butylicum)*
    - Lactic acid *(Lactobacillus)*
  - **Alcohol** → Ethanol *(S. Cerevisiae)*
  - **Enzymes**
    - Lipases (detergent)
    - Pectinase and protease (Clarified juices)
    - Streptokinase (clot buster)
  - **Bioactive molecules**
    - Cyclosporine A *(Trichoderma polysporum)*
    - Statins *(Monoscus purpureus)*
- **Biogas production**
  - **Methanogens** : *Methanobacterium* grow
    In aerobically on cellulosic material produce methane, CO_2 and H_2
  - **Gobar gas** – dung
  - **IARI and KVIC** (Developed biogas technology in India)
- **Biocontrol agents**
  - *Bacillus thuringiensis* – Caterpilars (Larva)
  - Lady bird – aphids
  - Dragonflies – Mosquitoes
  - *Trichoderma* – Plant pathogens
  - *Nucleopolyhedrovirus* – Inesct species specific
    e.g. Baculovirus
- **Biofertilisers**
  - Symbiotic – *Rhizobium* (Plant-bacteria)
  - Free living – *Azospirillum, Azotobacter*
  - Glomus – Mycorrhiza (Plant – Fungi)
  - Cyanobacteria – *Anabaena, Nostoc, Oscillatoria*